

SEQUENTIAL ELECTRONIC SYSTEMS

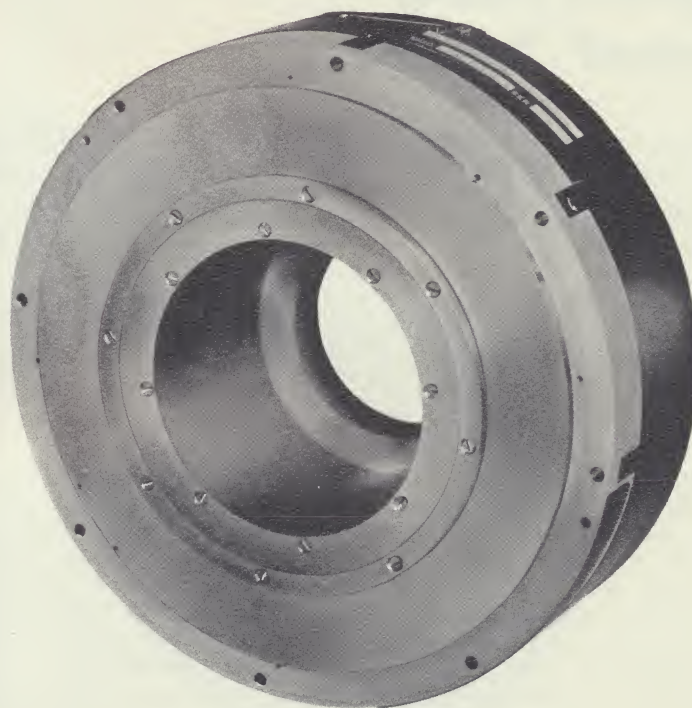
19 BIT NATURAL BINARY OPTICAL ENCODER

FEATURES

- 19 Bit resolution in 8 inch diameter housing
- All electronics self-contained in encoder housing
- Integrated circuit assemblies
- Printed circuit interconnections
- Modular construction
- Plug-in lamp assemblies, field replaceable
- Fiber optic disc illumination
- Unique locked-beam optical readout
- No trim adjustments
- Outputs unaffected by power supply variations and bulb aging
- One hour in-field MTTR
- Projected MTBF 15,000 Hours
- Meets all applicable MIL-Specs.

APPLICATIONS

- Star Trackers • Antennas
- Theodolites • Control Systems • Gimbal Systems
- Numerically Controlled Machine Tools • Inertial Platforms



SERIES 80NB

DESCRIPTION

The Sequential Natural Binary optical shaft angle encoder generates digital word representations of absolute angular rotations. The representation is directly obtained and presented in a natural binary format that can be continuously displayed, or interrogated on command by low-level electrical pulses.

All electro-optical assemblies and required electronic readouts, including output registers and interrogation circuitry, are wholly contained within the encoder housing. Electronic assemblies contain conservatively rated components and are fabricated with integrated microcircuits and packaged into functional modules. Modules are interconnected on printed circuit boards.

Reference light beams are d.c. excited and transmitted to proper readout stations via incoherent fiber optic bundles. The d.c. excitation enables a time-continuous digital readout. For maximum flexibility, and for operation with systems requiring interrogated outputs, associated integrated low-level logic circuitry and registers are included.

The encoder utilizes a precision natural binary optical disc manufactured by Sequential on its specially designed electrically-programmed automatic circle dividing machine. Bit accuracies on each track have been calibrated to a peak maximum position

error of 0.33 arc-seconds from any bit to any other arbitrary bit. Each track is synchronized to any other track with bit leading and trailing edges aligned to within a maximum inaccuracy of 0.5 arc-seconds.

A proprietary (patent pending) optical locked-beam technique is utilized in the readout of the fine tracks. The locked-beam enables outputs to maintain "set-in" phase relationships, independent of shaft position or direction of rotation. It also insures that the average d.c. level, about which any signal varies, is maintained at zero volts for wide variations in both lamp and system power supplies. The reliability of these zero levels directly reflect into the analog-to-digital conversion accuracy and represents a very significant improvement over the prior "state-of-the-art" in optical encoders.

All reading stations on the fine tracks are differentially read out, and the locked-beam provides an identical optical path from the bulb excitation filament to each silicon cell pickoff. Since the optical paths are the same for each station in a differential pair, relatively gross movements, resulting from either bulb replacement or variations in filament "hot-spot" due to bulb aging, will have no effect on the zero level or relative phasing from one readout station to any other, and will manifest itself



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only in changes of signal amplitude. This encoder series offers a unit in which aging or spatial orientation of the filament does not effect encoder performance. This advantage is further emphasized by the very significant increase in MTBF figure, related to catastrophic bulb failure only, over encoders in which filament aging effects must be considered. Encoders that exhibit critical dependence on filament position inherently do not have the capability of expeditious bulb replacement in the field, and require elaborate trimming procedures.

Physical limitations of ball-bearing assemblies, (sub-harmonics, runout, higher harmonic effects, and random errors) coupled with a small diameter encoder housing, places an upper limit on the number of tracks that can be directly viewed by the electro-optical system. This upper limit corresponds to a highest track density where digital bits read out at any one station, are aligned to within a total tolerance of one-half bit with respect to the digital bits readout at any other station on the same track. A unique Sequential optical phasing array, which acts in combination with mechanical phasing of the readout stations on the densest track, directly generates multi-phased electro-optical outputs with all point symmetric harmonic errors reduced to a level below 0.5 arc-seconds peak. The electrical signals corresponding to the optical outputs are phased such that phase displacements between signals correspond to the required resolution of the encoder. These signals are processed by digital vernier logic to precisely generate the remaining higher density bits.

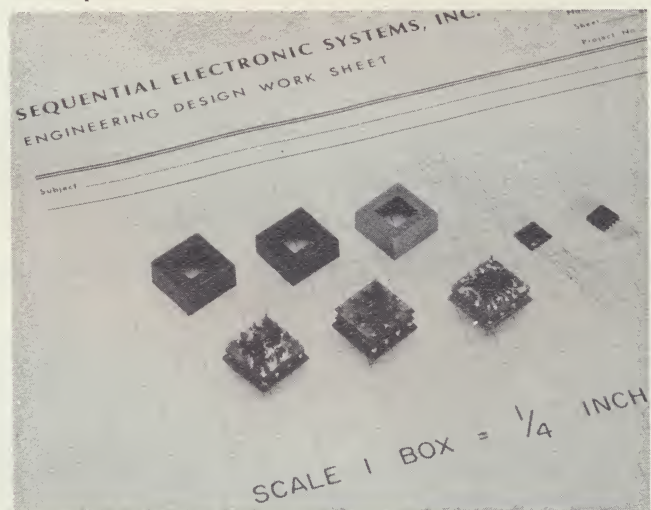
The digital vernier functions on the opto-mechanical level as differentiated from encoders which attempt to accomplish the same end by processing electrical outputs utilizing amplitude scaling and associated summations. Error analysis of the latter technique graphically illustrates the critical dependence of encoder accuracy on the stability of signal amplitudes with time, temperature, and spatial orientation (amplitude modulation of waveforms due to harmonic error cancellation). The Sequential digital vernier technique, due to its locked-beam optomechanical approach, is not dependent upon signal amplitude stability, and can tolerate wide variations in amplitude due to variations in light source intensity.

Serial U-scan logic is incorporated to prevent ambiguous readings. This logic inhibits transitions of all coarse tracks until the fine track transitions have occurred. Through this technique, all transitions are synchronized to the transitions occurring on the densest track. Total carry time delay in the serial logic is less than 4 micro-seconds. An internally generated "inhibit pulse", which is gated by transitions on the densest track, functions to prevent output changes until termination of the total carry time delay.

The accuracy of an encoding system compatible with a resolution of nineteen bits is available in a standard unit with a diameter of 8.0 inches and a depth of 2-13/16 inches. Units are available in either hollow-shaft or solid-shaft configurations. The standard hollow-shaft unit has a thru hole whose diameter is 2-7/16 inches. All Sequential encoders are designed to meet applicable MIL-specs.

HYBRID-MICROCIRCUIT FUNCTIONAL MODULES

There are three different types of microcircuit functional modules in the encoder readout amplifiers, buffer amplifiers and level detectors. Although several different circuit operations are required in the encoder, these are performed with only three basic modules, to reduce the number of module types used. All components are assembled on miniature printed circuit boards with soldering used to facilitate easy repair of these units. Each module has a 12 pin header which plugs into a printed circuit board. This printed circuit board interconnects all modules and eliminates costly wiring operations while increasing overall system reliability. All circuits are conservatively designed and power consumption is minimal.



ANALOG SIGNAL CONDITIONING ASSEMBLY

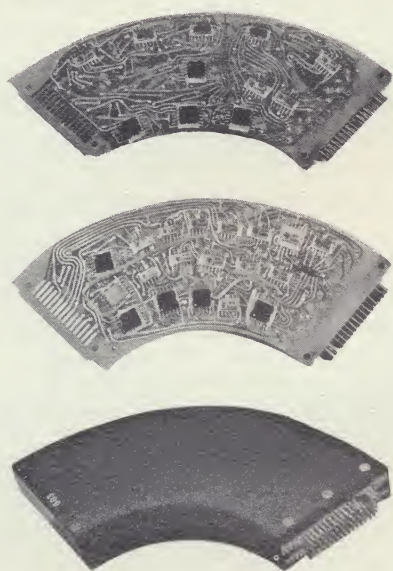
The plug-in signal conditioning assembly consists of hybrid-microcircuit buffer amplifier and level detector modules, interconnected on a printed circuit board. These modules shape the electrical output signals from the readout amplifiers to provide proper input signals to the digital logic. The readout amplifiers are located on the optics plate and monitor the high density tracks. In addition, the signal conditioning assembly directly monitors the outputs from the photosensors associated with the coarser tracks. Any module can easily be replaced in the field.



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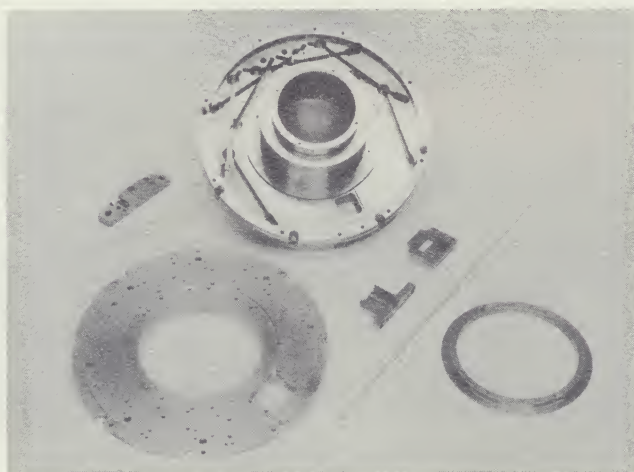
DIGITAL LOGIC ASSEMBLY

This assembly contains the U-scan logic, the vernier interpolation logic, the interrogation and inhibit logic, the output storage registers which hold the outputs between interrogations, and the output line drivers. The U-scan logic prevents ambiguous readings by synchronizing the transitions on each track to the fine-track transitions. The verniered outputs are digitally formed from the fine track readout signals. All interconnections are made on two printed circuit boards which are designed for field replacement of any sub-module. This assembly is built completely with integrated microcircuits, conservatively designed and having minimal power dissipation.



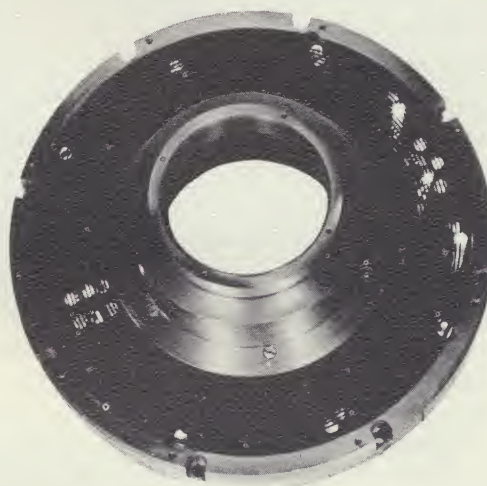
MECHANICAL ASSEMBLIES

Major mechanical assemblies for the encoder are illustrated. All parts are fabricated from stainless steel for structural rigidity and stability at all metal-glass interfaces.



ILLUMINATED OPTICAL DISC

All tracks on the disc are illuminated by two plug-in lamp assemblies. Fiber optics and associated lens assemblies transmit the light from the lamp assemblies to the appropriate reading stations.



CODED DISC

The coded disc consists of sixteen natural binary tracks. This optical disc was manufactured by Sequential on its unique electrically-programmed automatic circle dividing machine. Bit accuracies on each track have been calibrated to a peak maximum position error of 0.33 arc-seconds from any bit to any other arbitrary bit. All tracks are synchronized for bit transitions to within a maximum error of 0.5 arc-seconds.



COUPLINGS

In order to preserve the inherent high accuracy of the Sequential encoder, precision flexible couplings are required for mounting. Sequential has available flexible couplings specifically designed to hold wind-up and misalignment errors to negligible levels. These couplings are available as accessories.

SERIES 80NB



SPECIFICATIONS

QUANTA/REVOLUTION	2 ¹⁹
RESOLUTION	2.47 arc seconds
ACCURACY INCLUDING QUANTIZING-STANDARD DEVIATION	±1.1 arc seconds
ACCURACY INCLUDING QUANTIZING-PEAK DEVIATION	±2.47 arc seconds
ANGULAR ROTATION (1)	Continuous
ANGULAR VELOCITY FOR FULL ACCURACY	100 deg/sec
MAXIMUM SLEWING VELOCITY (OPERATING)	300 deg/sec
MAXIMUM SLEWING VELOCITY (NON OPERATING)	200 rpm
ANGULAR ACCELERATION FOR FULL ACCURACY	100 deg/sec ²
MAXIMUM READOUT DELAY – CARRY TIME PLUS INHIBIT TIME	4 microseconds
MAXIMUM INTERROGATION RATE	100 kc (Standard)
OUTPUT SIGNAL LEVEL	
LOGIC “1” (VOLTS POSITIVE)	4 ±1 volt into 2000 ohm load (2)
LOGIC “0” (VOLTS POSITIVE)	0.2 volts max. (2)
OUTPUT FORMAT	Parallel, 19 lines (3)
OUTPUT DISPLAY TIME (AFTER INTERROGATION)	Gated or continuous to suit customer requirements (4)
INTERROGATION PULSE INPUT	+ 6 volts into 120 ohms
BREAKAWAY TORQUE	5 oz – in
TEMPERATURE; OPERATING	–20°C to 65°C
TEMPERATURE; NON-OPERATING	–50°C to 100°C
HUMIDITY	.95% max.
INPUT POWER (5)	
VOLTAGE	+5 (^{+0.0} _{–0.5}) vdc +12 (±0.2) vdc –6 (±0.2) vdc
CURRENT	
+5 VDC	2.0 amps, max
+12 VDC	0.35 amps, max
–6 VDC	0.35 amps, max
REGULATION	±3%
RIPPLE	0.1%

NOTES

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| 1. Both solid and hollow shaft units are available. | coder's Digital Logic Assembly is available. |
| 2. Other logic levels are available. | 4. Auxiliary displays are available. |
| 3. Conversion to a serial format by an auxiliary package, or a direct serial output format from the encoder. | 5. Auxiliary power supplies are available. |



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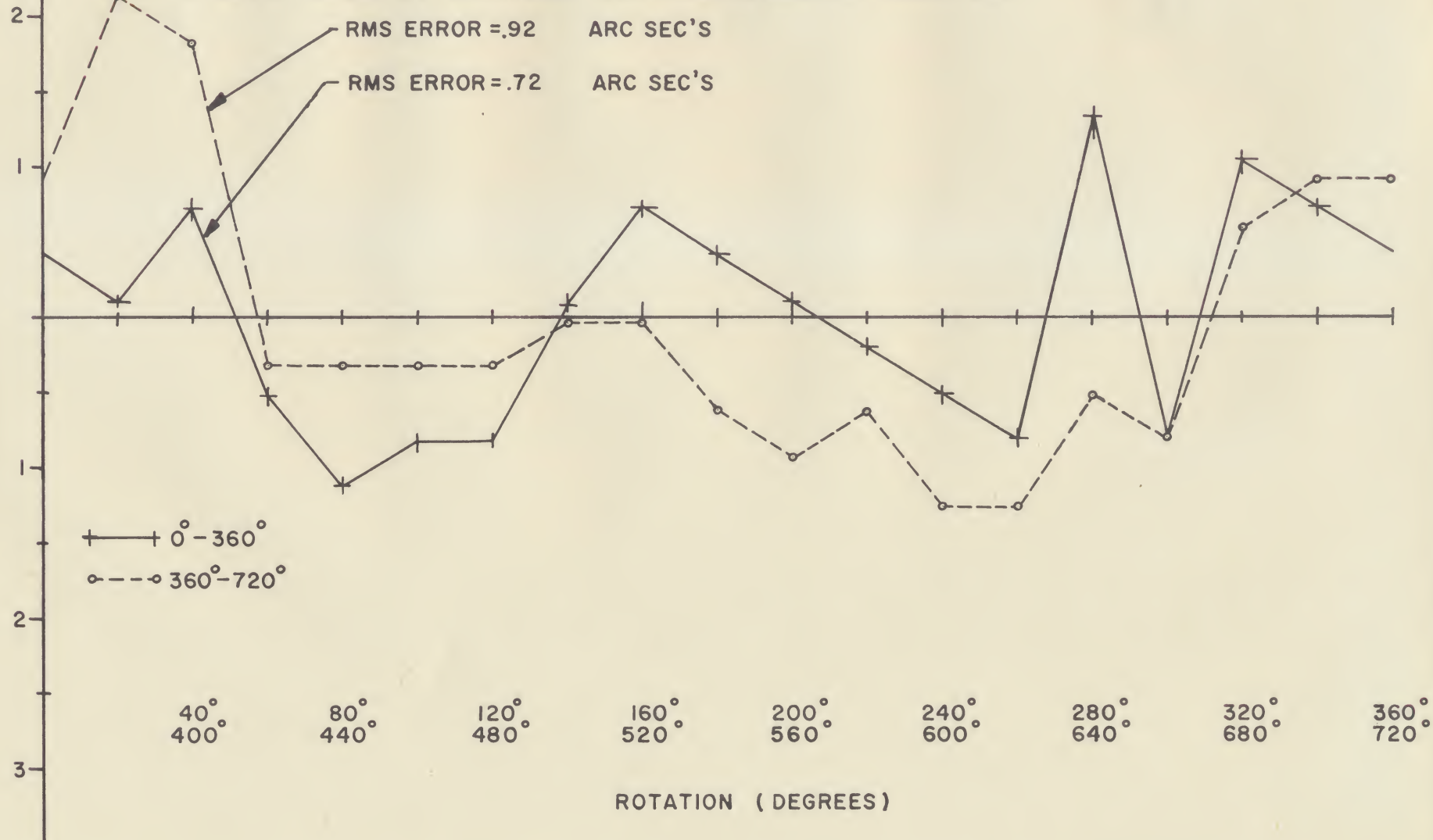
66 Saw Mill River Road, Elmsford, New York (914) LYric 2-8810 TWX 914 592 8368

ACCURACY TEST 19 BIT NATURAL BINARY ENCODER MODEL 80A-19NB-A SERIAL NO. 3

ERROR
(FROM MEAN)
ARC SECONDS

NOTES:

1. TEST PERFORMED WITH AN 18 SIDED POLYGON AND AUTOCOLLIMATOR, OVER TWO COMPLETE REVOLUTIONS OF ENCODER.
2. ACCURACY MEASUREMENT INCLUDES:
 - a. QUANTIZING ERROR: ± 1.24 ARC SEC (MAX.)
 - b. POLYGON ERROR: 0.6 ARC SEC, RMS
3. DATA TAKEN BY NORTHROP NORTHONICS, MARINE EQUIP. DEPT.

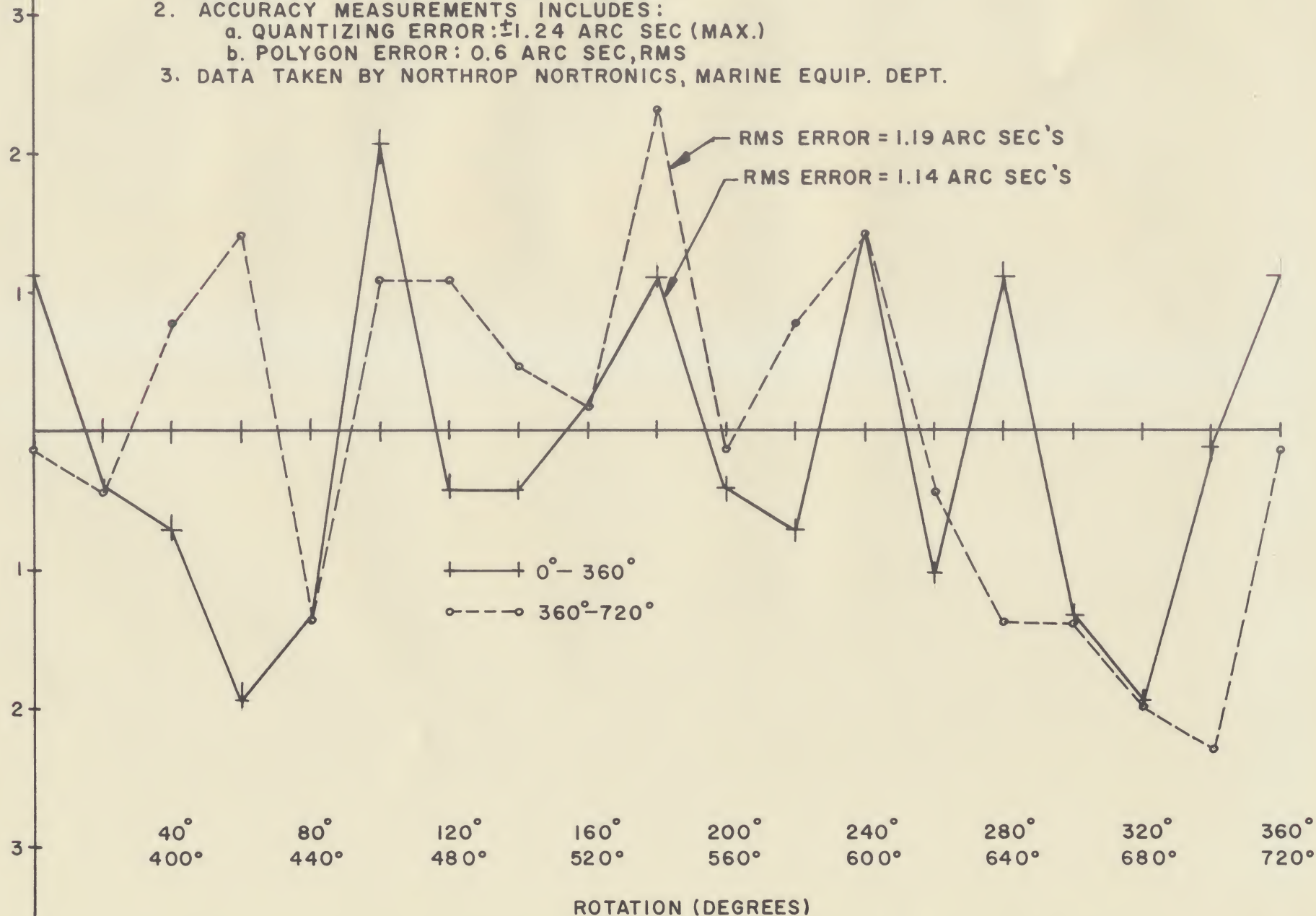


ERROR
(FROM MEAN)
ARC SECONDS

NOTES:

1. TEST PERFORMED WITH AN 18 SIDED POLYGON AND AUTOCOLLIMATOR, OVER TWO COMPLETE REVOLUTIONS OF ENCODER.
2. ACCURACY MEASUREMENTS INCLUDES:
 - a. QUANTIZING ERROR: ± 1.24 ARC SEC (MAX.)
 - b. POLYGON ERROR: 0.6 ARC SEC, RMS
3. DATA TAKEN BY NORTHROP NORTRONICS, MARINE EQUIP. DEPT.

ACCURACY TEST
19 BIT NATURAL BINARY ENCODER
MODEL 80A-19NB-A SERIAL NO. 4



ACCURACY TEST 19 BIT NATURAL BINARY ENCODER MODEL 80A-19NB-A SERIAL NO. 6

ERROR
(FROM MEAN)
ARC SECONDS

NOTES:

1. TEST PERFORMED WITH AN 18 SIDED POLYGON AND AUTOCOLLIMATOR, OVER TWO COMPLETE REVOLUTIONS OF ENCODER.
2. ACCURACY MEASUREMENTS INCLUDES:
 - a. QUANTIZING ERROR: ± 1.24 ARC SEC (MAX.)
 - b. POLYGON ERROR: 0.6 ARC SEC, RMS
3. DATA TAKEN BY NORTHROP NORTRONICS, MARINE EQUIP. DEPT.

